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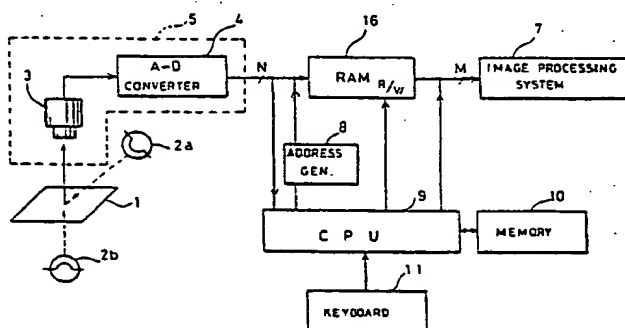
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54 Image input system.

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
X	EP-A-0 017 553 (COMPAGNIE GENERALE DE RADIOLOGIE) * Page 3, line 26 - page 4, line 6; page 6, line 26 - page 7, line 5 *	1,3	H 04 N 1/40
Y	---	1,3,4,7-9	
Y	DE-A-3 329 906 (MATSUSHITA ELECTRIC IND., CO.) * Page 17, line 15 - page 22, line 36; figures 2-5 *	1,3,4,7-9	
A	---	2,5,6	
A	FR-A-2 450 471 (FUJI PHOTO FILM CO.) * Page 15, lines 1-29; figures 1,4,6 *	1,2,5,6	
A	TELECOM REPORT, vol. 5, no. 2, April 1982, pages 92-97, Passau, DE; G. SING: "Chromagraph CP 340 - ein Universalscanner für die Reprrotechnik" * Page 95, left-hand column, lines 33-48; page 95, right-hand column, lines 19-29; page 96, middle column, lines 4-7; figure 7 *	1,3,4	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 08-02-1989	Examiner KLUZ F.M.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		I : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

## Image Input System

The present invention relates to an image input system, and more particularly to an image input system which optically reads an image of an object and converts the same into digital signals to be supplied to an image processing system.

In an image input system used as a first stage of an image processing system such as a facsimile or a process scanner, an image is generally photoelectrically read by a photoelectric converter such as a photomultiplier, an optical diode or a charge coupled device (CCD). However, as is well known in the art, the intensity of light incident upon the photoelectric converter from the original image is an exponential function of the optical density  $D$  of the image, and hence the levels of the analog electric signals output from the photoelectric converter are also an exponential function of the optical density  $D$ , and the output signals are not directly proportional to the optical density of the image. Therefore, the analog output signals from the photoelectric converter have generally been logarithmically transformed by means such as an analog operational amplifier to obtain output signals which are in linear relation to the optical density of the original image, in order to simplify the processing in the image processing system and improve gradation reproducibility. A circuit employing such an analog operational amplifier is relatively simple in construction, because it can be formed by one operational amplifier and a diode when an

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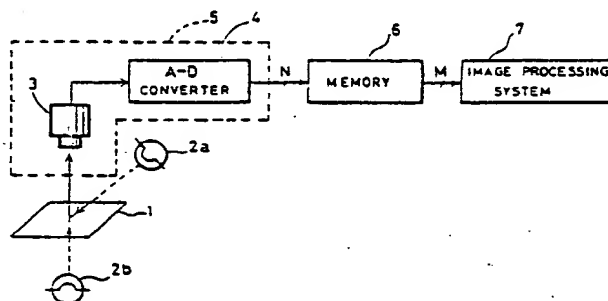
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57 Optical image data read by a photoelectric converter (3) are converted into N-bit digital signals by an A-D converter (4), and the digital signals are input to a look-up table memory (6) as address data. The memory (6) stores M-bit digital data which are linearly dependent on optical density of the image. Thus, the N-bit digital signals are transformed into the M-bit digital signals and a reproduced image obtained as an output of the memory (6) has a optical density which corresponds to that of the original image.



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being input, while the M-bit digital signals are linear with respect to the optical density of the original image. Since such transformation is performed between digital signals, high speed processing and stable transformation characteristics are obtained.

The linear relation between the M-bit digital signals and the optical density of the image may be varied in embodiments of the invention. Such an image input system further comprises a transformation characteristic specifying means for inputting linear relation specifying data for selecting a desired linear relation to supply transformation characteristics corresponding to the desired linear relation to the digital transformation means.

Thus, an optimum linear relation is selected in response to the optical density range of the image being input and the N-bit digital signals are transformed into the M-bit digital signals in the optimum linear relation to the optical density.

The present invention thus enables the provision of an image input system having stable and highly improved gradation reproducibility, and which can perform high-speed processing with excellent productivity.

In order that the invention may be readily understood, embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, in which:

FIGURE 1 is a block diagram showing a first embodiment of the present invention;

FIGURES 2 and 5 are graphs showing characteristics of the first embodiment;

FIGURE 3 is a graph showing characteristics of a

operational amplifier (so-called LOG amplifier) performing the said logarithmic transformation is utilized.

However, an analog operational amplifier formed by  
5 a semiconductor integrated circuit is inferior in frequency response and is not appropriate to high-speed processing. Further, the characteristics of the operational amplifier are generally unstable by temperature drift etc., and hence the gradation cannot be correctly reproduced. In  
10 addition, such a circuit employing the analog element cannot be easily adjusted, leading to inferior productivity.

The present invention aims to provide an improved image input system which photoelectrically reads the image  
15 of an object to supply signals representing the image to an image processing system.

Accordingly, the present invention provides an image input system for photoelectrically reading the image of  
20 an object and supplying electric signals representing the image to an image processing system, which image input system comprises: photoelectric conversion means for photoelectrically reading the image to convert the image into electric analog signals analog-to-digital converter  
25 means for converting the analog signals into N-bit digital signals; and digital data transformation means for transforming the N-bit digital signals into M-bit digital signals indicating values in a prescribed linear relation to the optical density of the image and delivering the M-bit  
30 digital signals to the image processing system, N and M being integers satisfying  $N > M$ .

The image read by the photoelectric conversion means is thus converted into N-bit digital signals, which in  
35 turn are transformed to M-bit signals by the digital data transformation means. The N-bit digital signals are non-linear with respect to the optical density of the image

embodiment;

Fig. 8 is a graph showing a treatment in the vicinity of maximum and minimum values of the optical density in the second  
5 embodiment; and

Fig. 9 is a graph showing a modification of a linear relation of the present invention.

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Fig. 1 shows the structure of an image input system according to a first embodiment of the present invention. In Fig. 1, reading light is emitted from a reflection light source  
15 2a or a transmission light source 2b on an original 1 to be inputted, which is recorded with an image having gradation. The light reflected by or transmitted through the original 1 is  
20 incident upon a photoelectric converter 3 included in the image input system through a well-known optical system (not shown). The image is sequentially inputted along the scanning direction of a well-known scanning mechanism (not shown) per fine pixel of  
25 the original 1.

Image data of the object (the original 1) thus optically inputted in the system are converted into analog electric signals by the photoelectric converter 3, to be further  
30 converted into N-bit digital signals ( $N = \text{integer}$ ) in an A-D converter 4 in a subsequent stage, through an appropriate amplifier (not shown). For convenience of illustration, the

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reference example;

FIGURE 4 illustrates data storage format of a memory employed in the first embodiment;

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FIGURE 6 is a block diagram showing a second embodiment of the present invention;

FIGURE 7 is a graph showing characteristics of the 10 second

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range of  $0 \leq D \leq D_0$ ,  $D_0$  represents the maximum value of the reproducible optical density and  $I_{D0}$  represents the value  $I_D$  when  $D=0$ . This functional form is depicted by symbol  $C_1$  in Fig. 2.

The second quadrant II in Fig. 2 shows the relation between outputs  $I_D$  from the photoelectric converter 3 and outputs  $S_N$  from the A-D converter 4, i.e., the input/output characteristics of the A-D converter 4. The outputs  $S_N$  are supplied as the N-bit digital signals, as hereinabove described. It is well known in the art that A-D conversion characteristics of the A-D converter 4 are substantially linear, and can be expressed by a straight line  $L_1$  as shown in Fig. 2. The functional form of the straight line  $L_1$  can be obtained from the following conditions, assuming that  $S_{N0}$  represents the output value  $S_N$  corresponding to the aforementioned maximum value  $D_0$ :

- (i) where  $I_D = I_{D0}$  (i.e.,  $D=0$ ),  $S_N=0$ ; and
- (ii) where  $I_D = I_{D0} \cdot 10^{-D_0}$  (i.e.,  $D=D_0$ ),  $S_N=S_{N0}$

and the result is as follows:

$$S_N = \frac{S_{N0}}{1 - 10^{-D_0}} \left( 1 - \frac{I_D}{I_{D0}} \right) \quad (2)$$

Eliminating  $I_D$  in the expression (2) by the expression (1), following expression (3) is obtained.

$$S_N = \frac{1 - 10^{-D}}{1 - 10^{-D_0}} \quad (3)$$

As obvious from the expression (3), the N-bit digital signals after the A-D conversion are also nonlinear with respect to the

photoelectric converter 3 and the A-D converter 4 are coupled  
be hereinafter referred to as an "input/conversion section 5".

The N-bit digital signals outputted from the  
5 input/conversion section 5 serve as address signals for a  
semiconductor memory 6 provided in a subsequent stage. In each  
address of the memory 6, M-bit digital data ( $M = \text{integer small}$   
than  $N$ ) obtained by an operation on the basis of prescribed  
10 expressions is previously stored as hereinafter described in  
detail. The M-bit digital signals corresponding to the M-bit  
digital data are outputted from addresses designated by the  
inputted N-bit, digital signals, to be supplied to an image  
15 processing system 7.

A description will now be given of the input/convers  
characteristics of the input/conversion section 5, with  
20 reference to Fig. 2. In the graph as shown in Fig. 2, the first  
quadrant I shows relation between the optical density  $D$  of th  
inputted image and outputs  $I_D$  from the photoelectric converte  
3. As hereinabove described, the analog outputs from the  
25 photoelectric converter 3 are an exponential functi  
of the optical density  $D$ , which can be expressed as follows,  
considering the amplifying gain in case that the outputs from  
the photoelectric converter element 3 are amplified by an ana  
30 linear amplifier (not shown):

$$I_D = I_{D0} \cdot 10^{-D} \quad (1)$$

where the original optical density is assumed to be within th

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5 may be obtained by performing processing with relatively large data length and that the image processing system 7 may perform processing with smaller data length while maintaining the good reproductibility. The memory 6 serving as the digital data transformation means is adapted to transform the N-bit digital signals received in the same into M-bit digital signals ( $N > M$ ) indicating values  $S_M$  in a prescribed linear relation to the optical density D, as shown by a functional form  $L_2$  in the fourth quadrant IV of Fig. 2. Thus, the values  $S_M$  to be outputted may be data in the following relation to the optical density D:

$$S_M = S_{M0} \left( \frac{D}{D_0} \right) \quad (4)$$

where  $S_{M0}$  represents the maximum value of the outputs  $S_M$  corresponding to  $D=D_0$ .

Since inputs  $S_N$  in the memory 6 are given by the expression (3) and the outputs  $S_M$  therefrom must be given by the expression (4), the transformation through the memory 6 must be performed on the basis of the following transformation relation (5), which is obtained by eliminating the value D from the expressions (3) and (4):

$$S_M = \frac{S_{M0}}{D_0} \log \left\{ \frac{S_{N0}}{S_{N0} - S_N (1 - 10^{-D_0})} \right\} \quad (5)$$

This functional relation is shown by  $C_2$  in the third quadrant III in Fig. 2.

Therefore, assuming that the right side of the expression (5) is expressed as  $f(S_N)$  as the function of the

optical density  $D$ .

For reference, now consider such case where the outputs from the input/conversion section 5 are directly supplied to the image processing system 7. In this case assuming that quantization errors in the  $N$ -bit digital signals  $S_N$  are represented by  $\Delta S_N$  as shown in Fig. 3, a density error  $\Delta D_{Q1}$  corresponding to the quantization error  $\Delta S_N$  in a low-density region is relatively small, whereas a density error  $\Delta D_{Q2}$  in a high-density region is considerably large. Therefore, if the data length (i.e.,  $N$ ) of the  $N$ -bit digital signals is decreased the optical density and the gradation are deteriorated in reproducibility in the high-density region. Thus, the gradation is caused to jump and accurate reproduction of fine gradation cannot be obtained.

On the other hand, when the data length  $N$  is increased to improve gradation reproducibility in the high-density region, cost of the image processing system would increase in proportion to  $N$  and this improvement would be impractical. Thus, when the outputs from the input/conversion section 5 as shown in Fig. 2 are directly supplied to the image processing system 7, problems are caused in the relation between the gradation reproducibility and the cost.

According to the present invention, therefore, a digital data transformation means (memory 6) is provided in order that the gradation reproducibility in the input/conversion section

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of a look-up table memory enables high-speed operation while productivity and stability are improved through the digital processing.

5           A description will now be given with reference to Figure 6 of a second embodiment of the present invention. The system as shown in Fig. 6 is different from that of Fig. 1 in the following points:

10 First, the memory 6 as shown in Fig. 1 is replaced by a RAM 16, so as to enable reloading of a look-up table stored therein. Further, the system as shown in Fig. 6 includes a CPU 9 which operates to give data required for transforming N-bit digital

15 signals into M-bit digital signals in response to a program stored in memory 10 and data (linear relation specifying data) inputted through a keyboard 11 as hereinafter described in detail. The data thus obtained are previously stored in

20 addresses of the RAM 16 designated by outputs from an address generator 8.

In order to clarify features of the second embodiment,

25 properties of the first embodiment will now be discussed from another point of view. When the optical density range of the image to be inputted, i.e., the range from high-light portions to shadow portions of the original is relatively wide

30 as  $D_{\min} \leq D \leq D_{\max}^{(A)}$  as shown at Fig. 7, substantially no problem is caused since the data range of the M-bit digital data  $S_M$  corresponding to the said optical density range is also wide as

inputs  $S_N$ , the memory 6 may be so structured as to output the functional value  $f(S_N)$  upon receiving the inputs  $S_N$ . In order to achieve such transformation, M-bits values  $f(x_1), f(x_2), \dots$  previously calculated on the basis of the expression (5) are stored in addresses (N - bit) respectively corresponding to a possible values  $x_1, x_2, \dots$  of the inputs  $S_N$  in this embodiment. Then the value  $S_M$  stored in the address designated by the received signal  $S_N$  is read out and is outputted to the image processing system 7. This is an application of the so-called look-up table memory.

In such system, the quantization errors  $\Delta S_M$  in the M-bit digital signals  $S_M$  correspond to a prescribed density error  $\Delta D_Q$  in respective regions of the optical density D. Therefore, even if the value M employed is relatively small, sufficient gradation reproducibility is ensured even in high-density regions.

For example, in case of  $N = 12$  bits,  $M = 8$  bits and  $D = 2.0$ , the density error  $\Delta D_Q$  in this embodiment is obtained as 0.008 (independent of D) on the basis of the expression (4). On the other hand, when memory 6 is not provided and the N-bit outputs from the input/conversion section 5 are directly supplied to the image processing system 7, the density error corresponding to sections of  $S_N = 254$  to 255 is 0.143, assuming that  $N = 8$  bits. Thus, the gradation reproducibility is remarkably improved in this embodiment. Further, the employment

$S_N$  corresponding to  $D_{\max}$  and  $D_{\min}$ . On the basis of this process, the CPU 9 operates to obtain transformation data based on a linear functional form passing through the two end points. An expression for giving the transformation data is obtained in the following manner:

The expressions (1) to (3) obtained on the basis of the functional forms  $C_1$  and  $L_1$  in Fig. 2 are also valid in the second embodiment. An alternative expression corresponding to the expression (4) is an equation for a straight line passing through the aforementioned two end points, which is formularized as follows:

$$(S_M - S_{\min})(D_{\max} - D_{\min}) = (S_{\max} - S_{\min})(D - D_{\min}) \quad (6)$$

The value  $D$  is eliminated from the expressions (3) and (6), to obtain the following expression:

$$S_M = \frac{1}{\Delta D} \left[ \Delta(SD) + \Delta S \log \left\{ \frac{S_{No}}{S_{No} - S_N(1 - 10^{-D_0})} \right\} \right] \quad (7)$$

where

$$\Delta D = D_{\max} - D_{\min} \quad (8)$$

$$\Delta S = S_{\max} - S_{\min} \quad (9)$$

$$\Delta(SD) = S_{\min} D_{\max} - S_{\max} D_{\min} \quad (10)$$

Symbol  $C_3$  in Fig. 7 shows the functional form represented by the expression (7). Thus, the variable transformation relation represented by the expression (7) may be properly specified by specifying the values  $D_{\min}$ ,  $D_{\max}$ ,  $S_{\min}$  and  $S_{\max}$  according to the conditions of original 1 to perform transformation corresponding thereto. Thus, within the required

(A)  
 $S_{\min} \leq S_M \leq S_{\max}$  as shown at Fig. 7. However, when the optical density range of the original image is narrow as  $D_{\min} \leq D \leq D_{\max}$  as shown at Fig. 7, the data range of the M-bit digital data  $S_M$  is inevitably narrowed as  $S_{\min} \leq S_M \leq S_{\max}$  as shown at Fig. 7. (B)  
 5 Therefore, the M-bit digital data  $S_M$  are only partially utilized although the same have the wide data range of  $0 \leq S_M \leq S_{M0}$ . For example, even if 8-bit digital data are prepared for  $S_M$ ,  
 10 gradation of the original image is merely expressed by a part of the  $2^8 = 256$  gradation levels. Thus, even if such data are transformed anew through a linear table, no clear reproduced image can be obtained due to jumps etc. caused in the gradation.  
 15 With respect to the image in the narrow density range  $D_{\min} \leq D \leq D_{\max}$ , (B) therefore, it is preferable to use such linear relation that the density range corresponds to most parts of the range of the M-bit digital data  $S_M$  as shown by  $L_3$  in Fig.  
 20 However, if the RAM 16 fixedly stores such transformation data based on the linear relation  $L_3$ , originals in wider density ranges cannot be treated. Thus, the system is so constructed  
 25 that the linear relation can be varied to enable appropriate selection.

In other words, the linear relation  $L_3$  is considered in such a manner that the end points  $(D_{\max}, S_{\max})$  and  $(D_{\min}, S_{\min})$  thereof are variable. Then, data of these end points are  
 30 arbitrarily inputted through the keyboard 11 as shown in Fig. 6 as "linear relation specifying data" to fetch respective value



for  $S_N$ . Upon obtaining the results of the operation, the CPU 9 supplies writing signals to a read/write selection signal input pin R/W of the RAM 16 while generating N-bit address signals corresponding to respective values of the N-bit digital data  $S_N$  through an address generator 8 to supply the same to the address part of the RAM 16. At the address of the RAM 16, corresponding M-bit data  $S_M$  obtained by the CPU 9 based on the expression (7) is stored. This storage relation is similar to that shown in Fig. 4. Namely, stored are M-bit digital data  $f(x_1), f(x_2), \dots$  corresponding to the respective ones of  $x_1, x_2, \dots$ , assuming that  $f(S_N)$  represents the functional form in the right side of the expression (7).

Upon completion of the writing operation, the CPU 9 supplies reading signals to the RAM 16. When the original 1 is set to be read out through the photoelectric converter 3, N-bit digital signals after A-D conversion are supplied to the address part of the RAM 16, which in turn outputs the M-bit digital data corresponding to the N-bit values. Upon completion of such processing in respective scanning directions, image input operation is completed with respect to one original 1. When another original image in a different density range is to be subsequently read, the said values  $D_{\min}, D_{\max}, S_{\min}$  and  $S_{\max}$  are inputted anew to perform similar operation, storage and reading.

With respect to accuracy in this embodiment, when, for example, the linear relation specifying data are given as  $D_{\min} =$

range, the amount of change of  $S_M$  with respect to constant change in the optical density is always constant to prevent jumps etc. of gradation.

5 In this case, however, there remain problems in transformation in the ranges of vicinity of the respective one of the maximum and minimum values, i.e.,  $0 \leq D \leq D_{\min}$  and  $D_{\max} \leq D \leq D_0$ . Such problems may be solved by connecting the linear  
10 relation to "limit transformation" as shown at  $a_1$  and  $a_2$  or "boost-up transformation" as shown at  $b_1$  and  $b_2$  in Fig. 8. The transformation  $a_1$  is appropriate as the printing characteristic for letterpress printing and the transformation  $b_1$  as that for  
15 offset printing.

On the basis of the above discussion, description is given of the operation of the embodiment as shown in Fig. 6  
20 within a range not overlapping with the above description.

First, a program for operating the expression (7) is stored in the memory 10 with the parameters  $D_{\min}$ ,  $D_{\max}$ ,  $S_{\min}$ ,  $S_{\max}$ . An operator inputs the optical density range of the  
25 original 1 to be inputted and the data range of the data  $S_M$  to be outputted in correspondence to the optical density range at the end point values  $D_{\min}$ ,  $D_{\max}$ ,  $S_{\min}$  and  $S_{\max}$ , through the keyboard 11.

30 On the basis of these data and the program stored in memory 10, the CPU 9 concretely specifies the expression (7) to operate the same with respect to all possible values  $x_1$ ,  $x_2$ .

linearity. In such case, a functional form representing the output characteristics of the input/conversion section 5 is set as  $S_N = F(D)$  to obtain the form of an inverse function  $F^{-1}$  of the function  $F(D)$ , thereby to obtain relation  $D = F^{-1}(S_N)$ . Therefore, input/output relation in the digital data transformation means is set on the basis of the following expression:

$$10 \quad S_M = k_1 F^{-1}(S_N) + k_2 \quad (11)$$

where  $k_1$  and  $k_2$  are constants.

From these expressions,  $S_M$  can be expressed as follows:

$$15 \quad S_M = k_1 D + k_2 \quad (12)$$

Thus, achieved is transformation for giving M-bit digital data indicating values in linear relation to the optical density D.

In case where the linear relation is varied as in the second embodiment, the values  $k_1$  and  $k_2$  are treated as variables and determined by the linear relation specifying data.

(ii) When the functional form corresponding to  $F(D)$  cannot be obtained by analytical expression, relation between D and  $S_N$  may be numerically obtained through use of a gray scale etc. to store  $S_M$  thus obtained in the memory 6 as shown in Fig. 1.

(iii) As to the system such as a facsimile for general public use, it may be required to be simple in operation while gradation reproducibility of reproduced images may not necessarily be high. In this case, the second embodiment can be

0.2,  $D_{\max} = 0.8$ ,  $S_{\min} = 0$  (0 % in reduction to the area rate of halftone dots in case of a process scanner) and  $S_{\max} = 255$  (100 % in the same case) assuming that  $N = 12$  bits,  $M = 8$  bits and  
5  $D_0 = 2.7$ , the image can be expressed in 230 gradation levels within the range of the area rate of halftone dots of 5% to 95%. Thus, the number of gradation levels is remarkably increased in comparison with 57 levels in the case of fixedly employing the  
10 linear relation  $L_2$  as shown in Fig. 2. Therefore, it is understood that, in addition to improvement by transformation based on the linear relation, a further effect is obtained by  
15 varying the linear relation to perform transformation in consideration of the range of density distribution of the original image.

Similarly to the first embodiment, further, employment  
20 of the aforementioned look-up table memory enables high speed operation while the digital processing improves productivity and stability.

25 Description is hereafter given of modifications of the present invention.

(1) Although the functional form represented by the expression (3) is assumed for the output characteristics of the  
30 input/conversion section 5 with respect to the optical density in the respective embodiments, this functional form may not be directly applied when a photoelectric converter is inferior in

"max". Assuming that, for example,  $D_{\max} = 0$  and  $D_{\min} = D_0$ , the expression (7) becomes the following expression (13)

5 
$$S_M = S_{M_0} - \frac{S_{N_0}}{D_0} \log \left\{ \frac{S_{N_0}}{S_{N_0} - S_N (1 - 10^{-D_0})} \right\} \quad (13)$$

When such relation is specified, negative/positive transformation is also performed in the image input system.

The present invention having the aforementioned  
 10 characteristics is also applicable to an input system for television video signals, in addition to the facsimile and the process scanner. In the case of the process scanner, the  
 15 gradation level can be changed through use of another look-up table after the M-bit digital signals are obtained.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is  
 20 by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

25 The features disclosed in the foregoing description, in the claims and/or in the accompanying drawings may, both separately and in any combination thereof, be material for realising the invention in diverse forms thereof.

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carried out as follows:

The density ranges etc. of the images to be inputted are restricted to several types. Under the circumstances, linear relationships corresponding to the respective density ranges are derived and transformation data obtained therefrom are previously stored separately in a plurality of memories or different areas of a mass storage memory. Simple selection switches etc. may be used as the "transformation characteristic specifying means". In response to the selection by the selection switches, a memory receiving the N-bit digital signals is selected to output the M-bit digital data stored therein. In this case, the variable range of the linear relation is over the aforementioned several types. The term "variable" used in connection with the present invention includes such discrete variability as well as continuous variability.

(iv) The transformation formula represented by the expression (5) can be employed as a special case in the variable linear relation, because the aforementioned problems may be caused only when the same is fixedly employed.

In fact it is easily confirmed that the expression (7) becomes the expression (5) assuming that  $D_{\min} = 0$  and  $D_{\max} = D_0$  in the expression (7), and hence it is understood that the expression (7) includes the expression (5).

Further, the data  $D_{\max}$  may be less than the data  $D_{\min}$  regardless of the ordinary meaning of subscripts "min" and

of the expression (a) in respective addresses corresponding to the values  $S_N$  as data respectively to output corresponding said values  $S_M$  as said M-bit digital signals every time said N-bit digital signals are inputted.

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4. An image input system according to claim 1, comprising transformation characteristic specifying means (8, 9, 10, 11) inputting linear relation specifying data for selecting a desired linear relation thereby to supply  
10 transformation characteristics corresponding to the desired linear relation to the digital data transformation means (16).

5. An image input system according to claim 4, wherein  
15 the linear relation specifying data include two optical density values  $D_{\min}$  and  $D_{\max}$  indicating end points of the optical density range of the image and two values  $S_{\min}$  and  $S_{\max}$  indicating end points of range and values to be indicated by said M-bit digital signals; and digital  
20 data transformation means (16) performs transformation on the basis of the following expression (b) determined by said values  $D_{\min}$ ,  $D_{\max}$ ,  $S_{\min}$  and  $S_{\max}$ :

$$S_M = \frac{1}{\Delta D} \left[ \Delta (SD) + \Delta S \log \left\{ \frac{S_{NO}}{S_{NO} - S_N(1 - 10^{-D_0})} \right\} \right] \quad (b)$$

25 where

$D$  represents the optical density of the image,

$D_0$  represents the maximum value of reproducible optical density,

30

$S_N$  represents values indicated by the N-bit digital signals,

$S_M$  represents values to be indicated by the M-bit  
35 digital signals in correspondence to the values  $S_N$  and

$S_{NO}$  represents a value  $S_N$  corresponding to the value

CLAIMS

1. An image input system for photoelectrically reading the image of an object and supplying electric signals representing the image to an image processing system, which image input system comprises: photoelectric conversion means (3) for photoelectrically reading the image to convert the image into electric analog signals analog-to-digital converter means (4) for converting the analog signals into N-bit digital signals; and digital data transformation means (6 or 8 to 11 and 16) for transforming the N-bit digital signals into M-bit digital signals indicating values in a prescribed linear relation to the optical density of the image and delivering the M-bit digital signals to the image processing system (7), N and M being integers satisfying  $N > M$ .

15

2. An image input system according to claim 1, wherein: the said linear relation is valid within a range of 0  $D \leq D_0$ , D being the optical density of the image and  $D_0$  being the optical density of the image and  $D_0$  being the maximum value of reproducible optical density; and the digital data transformation means performs transformation on the basis of the following expression (a):

$$S_M = \frac{S_{M0}}{D_0} \log \left\{ \frac{S_{N0}}{S_{N0} - S_N (1 - 10^{-D_0})} \right\} \quad (a)$$

25

where  $S_N$  represents values indicated by the N-bit digital signals,  $S_M$  represents values to be indicated by the M-bit digital signals in correspondence to the values  $S_N$ ,  $S_{N0}$  represents a value  $S_N$  corresponding to the value  $D_0$ , and  $S_{M0}$  represents a value  $S_M$  corresponding to the value  $D_0$ .

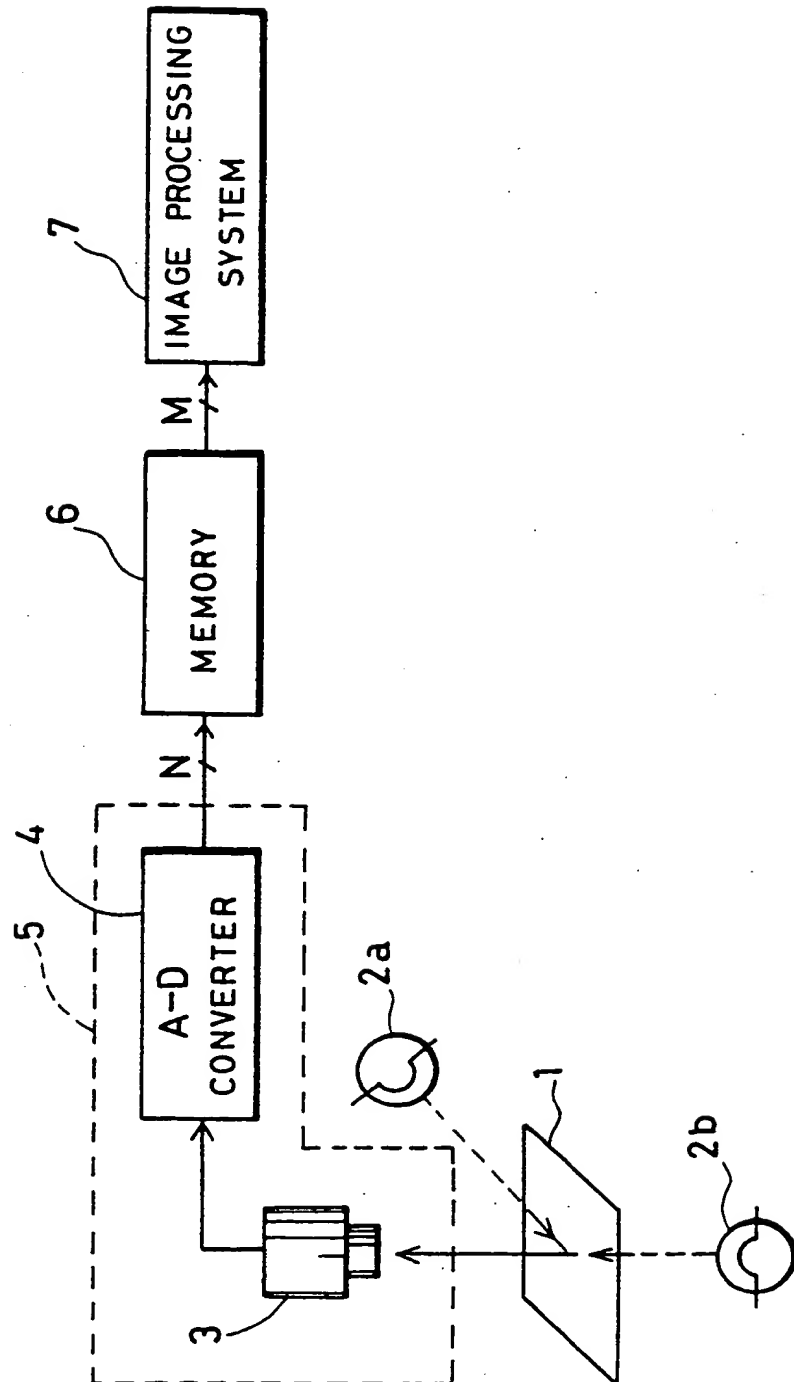
3. An image input system according to claim 2, wherein: the digital data transformation means includes memory means (6) storing said values  $S_M$  obtained on the basis

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FIG. 1



$D_0$ ,  
where

$$\begin{aligned}\Delta D &= D_{\max} - D_{\min}, \\ \Delta S &= S_{\max} - S_{\min}, \text{ and} \\ \Delta(SD) &= S_{\min}D_{\max} - S_{\max}D_{\min}.\end{aligned}$$

6. An image input system according to claim 5, wherein the transformation characteristic specifying means includes operational means (11) for inputting data representing the values  $D_{\min}$ ,  $D_{\max}$ ,  $S_{\min}$  and  $S_{\max}$  to perform operation on the basis of the expression (b); and the digital data transformation means includes memory means storing the values  $S_M$  in respective addresses corresponding to the values  $S_N$  as data on the basis of outputs from the operation means to output corresponding values  $S_M$  as said M-bit digital signals in response to inputting of the N-bit digital signals as address signals.
7. An image input system according to claim 4, wherein the linear relation specifying data is arbitrarily selectable from continuous values.
8. An image input system according to claim 4, wherein the linear relation specifying data is arbitrarily selectable from discrete values.
9. An image input device according to claim 4, wherein the linear relation is selected to limit transformation or boost transformation in the vicinity of respective ones of the maximum and minimum values of the optical density of the image.

FIG. 2

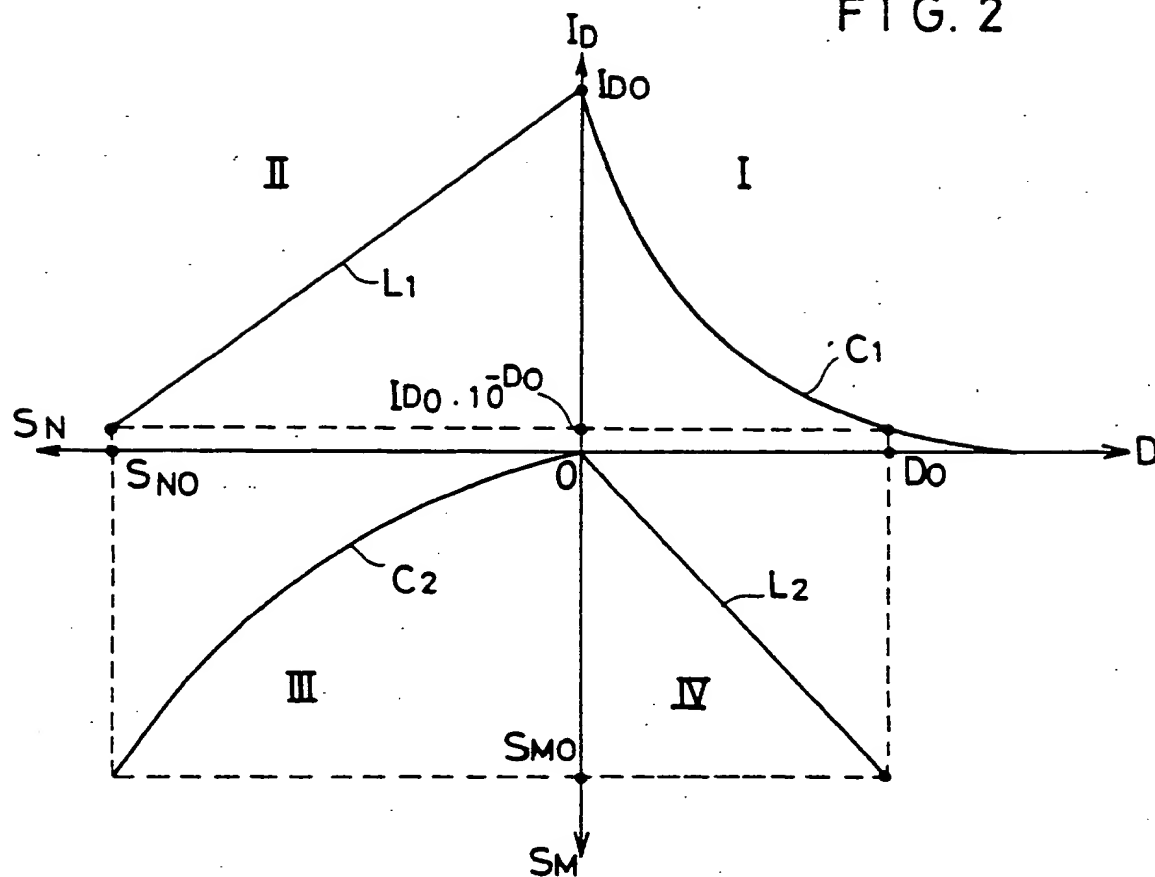
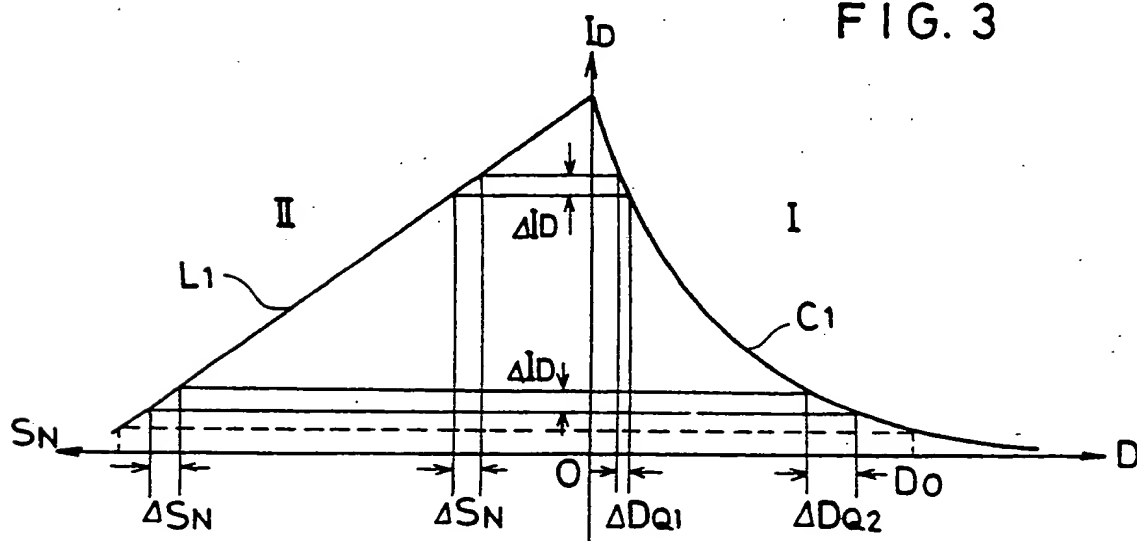


FIG. 3

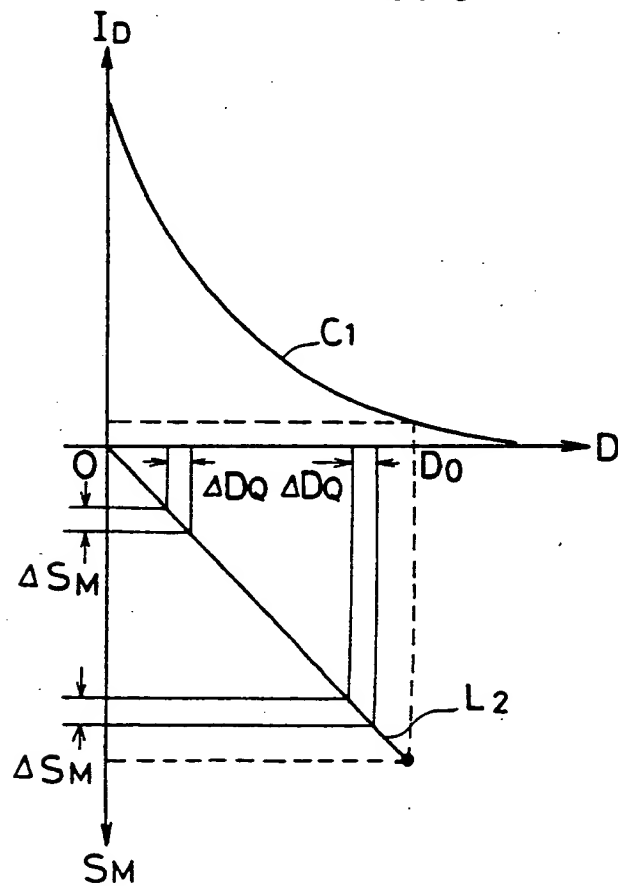


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FIG. 4

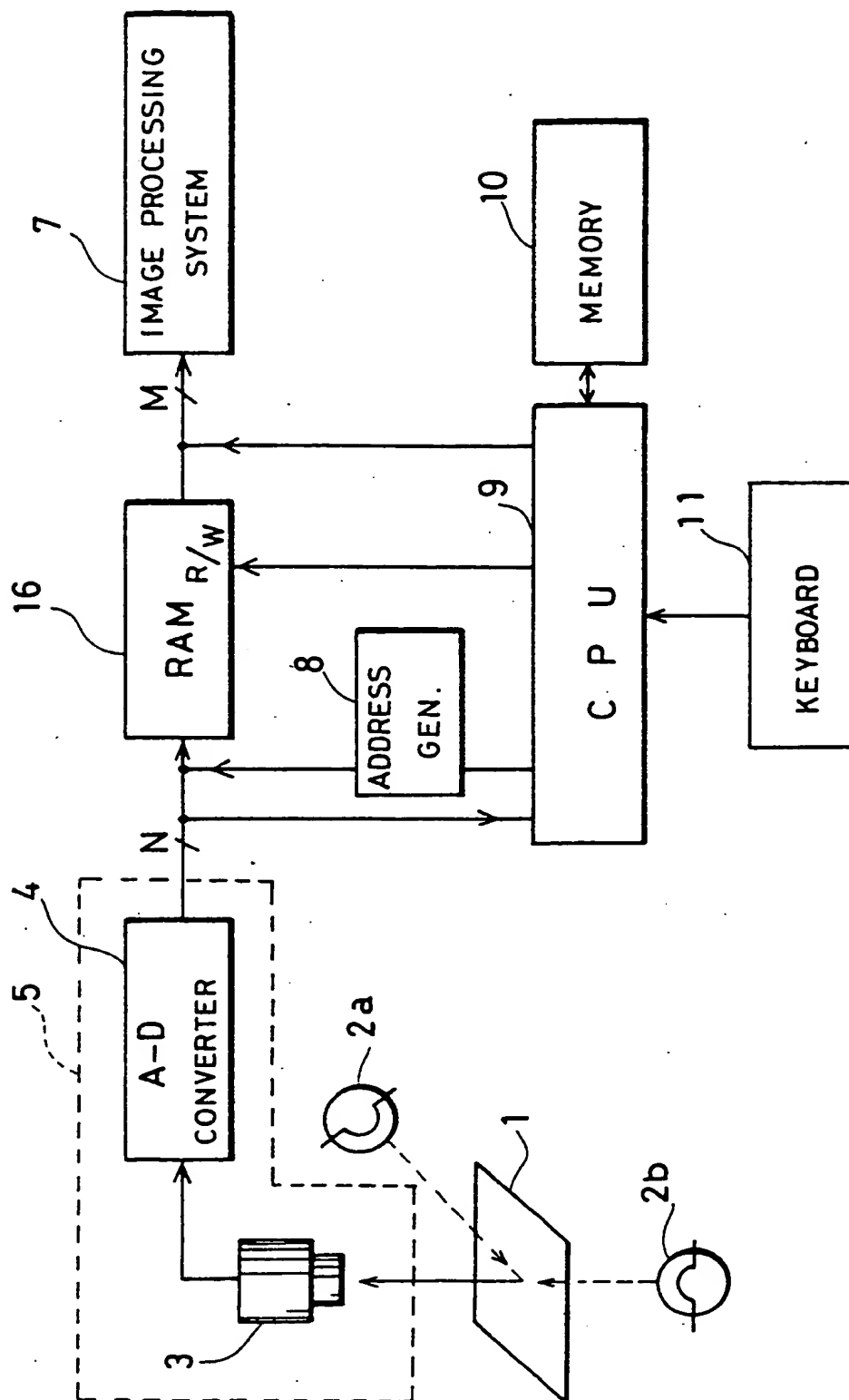
ADDRESS(N-BIT)	DATA(M-BIT)
$X_1$	$f(X_1)$
$X_2$	$f(X_2)$
$X_3$	$f(X_3)$
$X_4$	$f(X_4)$

FIG. 5



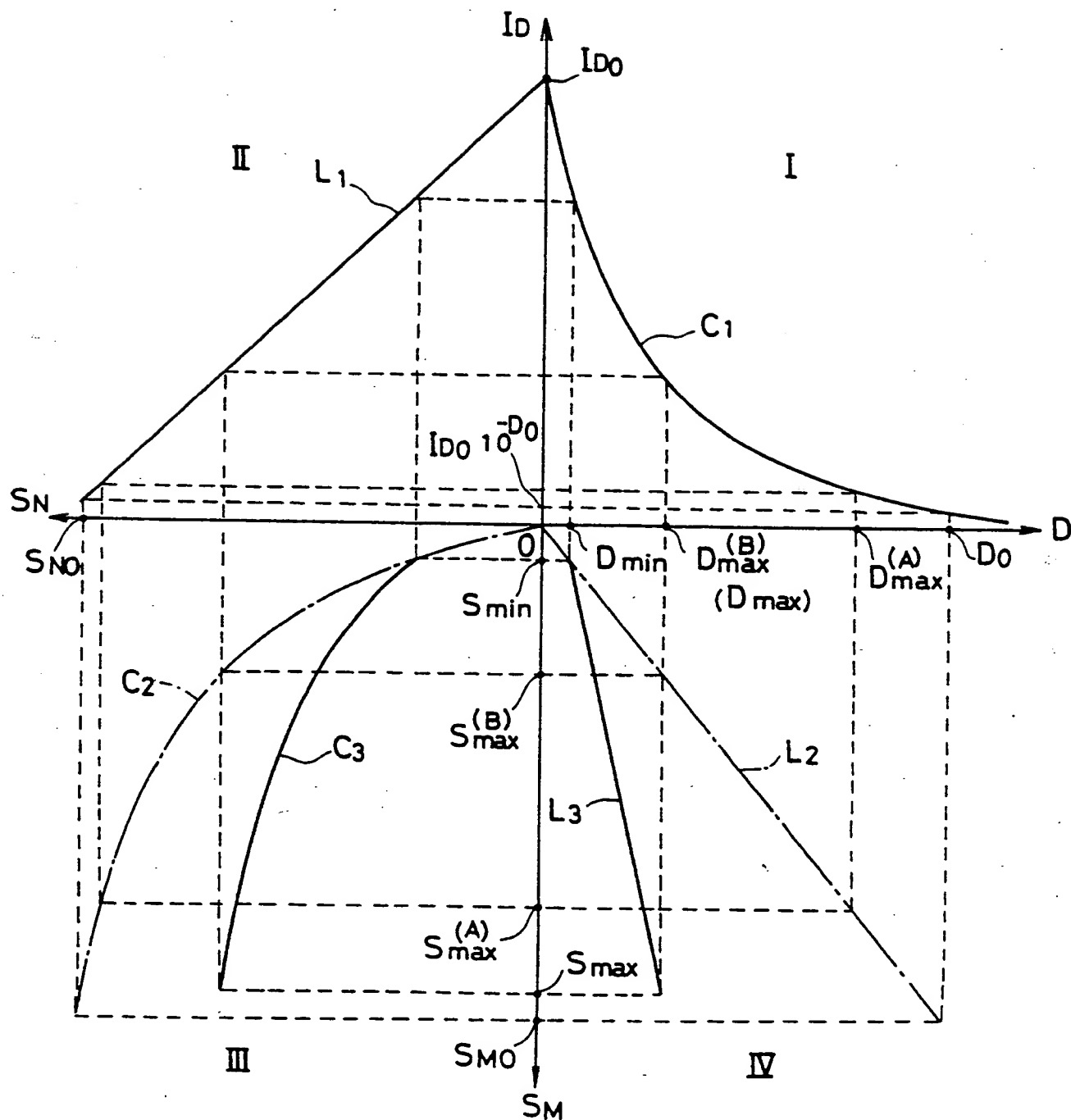
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FIG. 6



S(6

FIG. 7



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FIG. 8

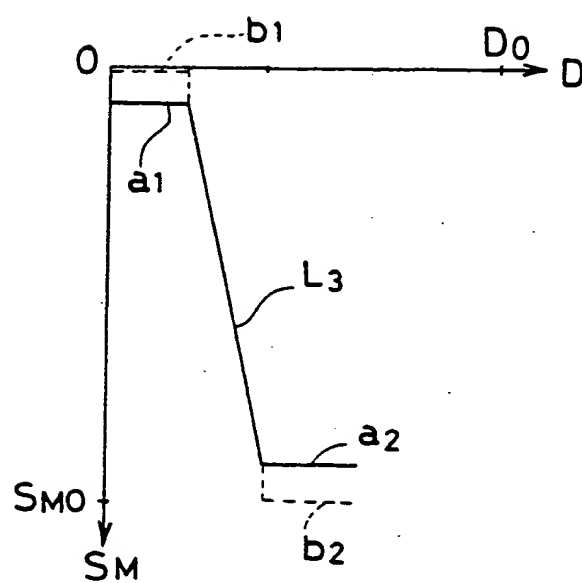
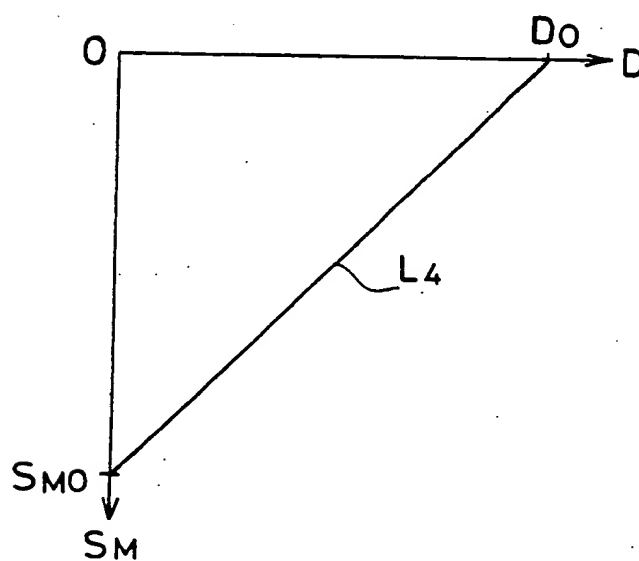


FIG. 9



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